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HUMAN FACTORS ENGINEERING DESIGN CRITERIA FOR FUTURE SYSTEMS. REPORT NO. 1: TANK DESIGN CRITERIA EVOLVING FROM THE M1 TANK OPERATIONAL TEST III

ARI Field Unit at Fort Hood, Texas
Systems Research Laboratory

March 1984

U.S. ARMY RESEARCH INSTITUTE for the BEHAVIORAL and SOCIAL SCIENCES

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Human factors engineering (HFE) design problems reported in the M1 battle tank Operational Test III were compared with criteria in MIL-STD-1472C and MIL-HDBK-759A to determine criteria adequacy. Adequate criteria were viewed as critical and should be given greater emphasis in future programs. New criteria were proposed for inadequate or missing criteria. Approximately 80 percent of the HFE problems related to conventional technological components were found to be covered by current criteria which provide adequate guidance for resolving

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such problems. The remaining 20 percent were covered by inadequate criteria. Revised criteria were proposed for these items. In contrast, only about 54 percent of HFE problems related to new technological components were covered by adequate criteria; 36 percent had inadequate criteria and nine percent had no criteria. Revised and new criteria were proposed for the latter two groups. The findings indicate that a large proportion of current criteria do not contain sufficient guidance for incorporating good HFE design into new technology.

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Human Factors in Training &
Operational Effectiveness

FOREWORD

A major research project of the Army Research Institute (ARI) Field Unit at Fort Hood, Texas, is "Evaluating Human Factors Considerations and Concepts in an Operational Environment" (Army Project 2Q263739A793). This project is primarily concerned with evaluating the human factors (man-machine interface) aspects of systems in an operational environment; the purpose is to optimize performance of existing systems and provide design criteria for future similar systems. One of these evaluations was the human factors evaluation of the M1 Battle Tank during Operational Test III. This report describes the results of an analysis of data from the OT III, the selection of current criteria and development of new criteria. These criteria provide the design guidance necessary for: 1) resolving current human factors engineering problems with the M1 tank, and 2) preventing the recurrence of such problems in future tank systems. The report does not address current design criteria which are adequate and which were properly considered during the RDT&E process, i.e., design criteria relating to system aspects where no man-machine interface problems were found.

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HUMAN FACTORS ENGINEERING DESIGN CRITERIA FOR FUTURE SYSTEMS REPORT NO. 1: TANK DESIGN CRITERIA EVOLVING FROM THE M1 TANK OPERATIONAL TEST III

EXECUTIVE SUMMARY

Requirement

The objective of this analysis is to specify current human factors engineering (HFE) related design criteria that are associated with current M1 tank deficiencies and to stipulate new design criteria, where needed, in order to prevent a recurrence of these problems in future tank systems.

Procedure

The procedure involved comparing individual HFE design problems identified in the M1 Tank Operational Test III with relevant criteria statements containing the information for avoiding such problems in the design process. The criteria in MIL-STD-1472C and MIL-HDBK-759A were evaluated to determine if they provided adequate guidance for making informed design judgements. Criteria judged as adequate were viewed as critical criteria that should be given greater emphasis in future programs. In comparisons in which the criteria were judged as inadequate or missing, revised or new criteria were proposed.

Findings

Of the HFE problems common to both the M1 tank and previous similar systems, approximately 80 percent are covered by current criteria which provide adequate guidance for resolving such problems. These problems make up three quarters of the HFE problems in the M1 tank system and could have been avoided had greater emphasis been given to adhering to requirements established by current criteria.

Twenty percent of the problems common to both the M1 tank and previous similar systems were related to inadequate design criteria that did not provide the required information. This finding indicates that the current (previously existing) criteria are of uneven quality.

The situation with new technology is much different. Only about 54 percent of the identified HFE problems designed into components that are new to the M1 were found to be covered by adequate criteria; 36 percent had inadequate criteria; nine percent had no criteria. These findings indicate that a large proportion of current criteria do not contain the information sufficient for incorporating good HFE design into new technology. It points out a definite need to update old design criteria and add new criteria concurrently with applications of new technology. Preferably, the new and updated criteria should be available when new technology is being designed into new tank systems.

Utilization

These findings are intended for use in improving and updating HFE design criteria for battle tank systems. The critical, revised and new criteria presented in this report provide much of the information necessary for correcting the current HFE problems in the M1 tank and preventing the recurrence of similar problems in future generation tank systems.

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INTRODUCTION

The Fort Hood Field Unit of ARI has an active program of human factors research with new and improved equipment in the system acquisition process. The research is characterized by assessment of systems in an operational environment when these systems are manned by regular FORSCOM troops for the first time. ARI provides support to TCATA, test boards and OTEA in fulfulling the requirements of the human factors objectives of operational tests conducted by these agencies. This report is the first in a series of reports on developing design criteria for future systems.

PURPOSE AND OBJECTIVE

One of the primary functions of the ARI human factors research program is to provide human factors engineering (man-machine interface) design criteria for future systems. This is achieved by an analysis of human factors engineering (HFE) problems identified in user tests of similar current systems. Problems identified in current systems, therefore, serve as the basis for establishing critical design criteria for future similar systems - a process that involves: (1) detecting relevant existing design criteria which have been overlooked or ignored, and (2) identifying and developing new criteria for unanticipated problems not covered by current standards.

The objectives of this current analysis are limited to: (1) specifying current HFE related design critieria that are associated with current M1 tank deficiencies; and (2) stipulating new design criteria, where needed, in order to prevent a recurrence in future systems of HFE problems reported in: Human Factors Evaluation of the M1 Battle Tank in Operational Test III, an ARI report included in TCATA test report: New Army Battle Tank (XM1) Operational Test III (OT 58), (August 1981), and also included as a section of OTEA test report: Independent Evaluation of the M1 Main Battle Tank, (November 1981). This analysis does not address current design criteria (specifications) which are adequate and which were properly considered during the RDT&E process, i.e., design criteria relating to system aspects where no man-machine interface problems were found.

PROCEDURE

The approach involved comparing the individual HFE problems described in the above report with the applicable criteria statements containing the rules for avoiding the problems. The problems were first identified with the related hardware components and arranged accordingly. The components themselves were classified as either conventional or new. A conventional component was defined as a design or technological application used in previous generation tank systems whereas a new component was one not used previously in tank systems. This distinction was made to identify criteria involved where applications of new technology have occurred. New technology often creates the need to revise and update criteria so they include new HF considerations generated by the new technology. Thus criteria covering new technology become prime candidates for revising.

The criteria reference sources used in the search were the current issues of MIL-STD-1472 and MIL-HDBK-759, namely, MIL-STD-1472C (1981) and MIL-HDBK-759A (1981). During the period of M1 tank development in the 1970's, however, it is likely that prior editions - MIL-STD-1472B (1974) and MIL-HDBK-759 (1975) - were the versions available for contract application and guidance. The latest editions were used in this analysis because the main purpose was to produce information to update and revise current standards. Both references were examined to identify those criteria that are pertinent for each problem. Criteria that were judged to be relevant to some degree were included in the selections. The selected criteria were then evaluated to determine whether or not they provided unequivocal and specific guidance for making informed design judgments. In cases where the criteria were judged as adequate in providing sufficient guidance, these were defined as critical criteria that should be given greater consideration or emphasis in future programs.

In cases where the existing criteria were judged as relevant but providing inadequate guidance, the comparisons revealed the need for revision to include guidance covering the HFE considerations involved in the design problem. Revised design criteria were then formulated for these cases.

In cases where searches ended with no relevant criteria found, the situations were viewed as representing conditions not covered by current standards. New criteria were formulated in these cases.

RESULTS

Design criteria data are presented in tables made up of three columns. The first column presents HFE problems described in succinct statements indicating the identity of the hardware components involved, whether they are conventional or new components and the specific design features causing the problems. In the second column, adjacent to the statements of the HFE problems, are presented relevant current criteria, if any. Each design criterion is presented in a short statement and paraphrased where necessary to include only the parts relevant to the problem. Each criterion statement ends with a number in parenthesis. This number refers to a specific paragraph in the reference sources. Numbers beginning with the letter "S" indicate MIL-STD-1472C and the specific paragraph therin. Numbers beginning with the letter "H" indicate MIL-HDBK-759A and its paragraph number.

The third column presents the proposed new or revised criteria. In cases where the relevant criteria were judged as adequate, no new criteria are presented and the statement "No change" is entered in the column. In other cases where the relevant criteria were judged as inadequate or where no relevant criteria were found, new or revised criteria are included.

The results are organized into two tables according to problem severity. Table 1 addresses the 24 hardware components in the M1 Tank OT III report judged to have major HFE problems causing significant decrements in operational effectiveness. Table 2 addresses 46 other hardware components with HFE problems judged to be general problems which have a less severe impact on system effectiveness but which, nonetheless, will result in degradation of combat effectiveness.

Table 1

Comparisons of Major HFE Design Problems in the
M1 Tank OT III Report with Current and Proposed Design Criteria

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
Section A. Commander's Station		
1. Power control handle (conventional component)		
1.1. The handle is located too low to reach when operating in the standing open hatch position.	Controls should be designed and located so that the full range of Army personnel can operate them without having to assume awkward positions. Crew members with task descriptions that require the assumption of several working postures, (seated, standing, etc.) should have controls which can be easily used in each required posture (H 7.6.1).	No change.
2. Commander's weapon remote controls (new component)		
2.1. The elevation, traverse and trigger controls are difficult to coordinate and operate.	Control complexity and precision shall not exceed the operator's manipulative capability (S 5.1.1.3).	No change.
2.2 It is difficult to acquire and track targets.	Same as above (S 5.1.1.3).	No change.

Table 1 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
2.3. The traverse control has a poor force/displacement ratio.	Control display ratios for continuous adjustment controls minimize the total time required to make the desired control movement (i.e., slewing time plus fine adjustment time) (S 5.1.4.1).	No change.
2.4. The present combination of powered and manual traverse controls with only manual elevation and trigger controls is unsatisfactory.	The gunner should have both power and manual control of the gun system in elevation and azimuth and should be able to operate them in either mode, without substantial loss of efficiency, while wearing appropriate handware (H 7.6.1.1).	No change.
3. Commander's seat (conventional component)		
3.1. There is no seating provided for open hatch operation which is the operating mode used most of the time.	Work seating shall provide an adequate supporting framework for the body relative to the activities that must be carried out (S 5.7.3.4.1). The commander's seat should adjust to provide good open hatch surveillance and comfortable access to all sights and viewing devices (H 7.5.9.2.1).	Work seating should be provided to tank commanders for all of their operating positions, namely, closed hatch, protected open hatch and open hatch. Open hatch seating should be equipped with an instant stowage capability to allow the commander unobstructed emergency entry into the turret when hazardous conditions occur suddenly (S 5.12.10.1).*

* The proposed change has been reviewed and revised by members of the Tri-Service Technical Group for MIL-STD-1472 and submitted to the group for adoption as a revision of or a change notice to MIL-STD-1472.

Table 1 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
4. Automatic engine shutdown function (acuated by low oil pressure) (new component)		
4.1. There is the need to provide a by-pass (battle-short) switch to keep the tank engine operating in combat situations.	No relevant criteria found.	Unless activation would result in a catastrophe, a battle-short switch, bypassing all safety switches should be provided (S 5.12.10.2).*
5. Mounts for the commander's weapon station control handle (conventional component)		
5.1. The pointed mounts are safety hazards endangering the commander.	Sharp edges and corners that present a personal safety hazard shall be suitably protected (S 5.13.5.4).	No change.
6. Eyecups on gunner's primary sight extension (conventional component)		
6.1. Commanders cannot acquire proper sight pictures when wearing the protective mask.	Eyecups shall be compatible with helmets, protective masks, and other clothing and personal equipment (S 5.11.3.14.3).	No change.
Section B. Loader's Station		
1. Workspace (conventional component)		
1.1. Workspace was rated to be inadequate for loading task requirements.	Workspace design and sizing shall insure accommodation, compatibility operability and maintainability by at least 90 percent of the user population (S 5.6.1).	No change.

Table 1 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
2. AM 1780/VRC radio amplifier (conventional component)		
2.1. The 1780 is located in a position exposing it to damage hazards.	The radio set should be located where normal system operations and crew activities are not likely to damage it (H 7.3.6).	No change.
Section C. Gunner's Station		
1. Gunner's primary sight (GPS) (new component)		
1.1. The sight's external lens is not equipped with a lens cleaning device.	Windshield wipers and washers shall be provided. Blades shall return to the stowed position when turned off. Provision shall be made for manual operation in event of power failure (S 5.12.5.8). Optical instruments exposed to adverse weather conditions shall be provided. These would include windshield wipers, defoggers and defrosters, etc. (H 7.7.4).	Powered windshield wipers, washers and defrosters shall be provided. Blades shall return to the stowed position when turned off. Provision shall be made for manual operation in event of power failure (S 5.12.5.8).*
2. Eyecups on GPS (conventional component)		
2.1. The eyecups on the GPS and the NBC protective mask are incompatible.	Same as Section A-6. (S 5.11.3.14.3).	No change.

Table 1 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
3. Thermal imaging system (TIS) power supply unit (conventional component)		
3.1. The turret heater vent overheats the power supply causing the TIS to malfunction.	There should be enough ventilation to keep parts and materials from getting so hot that they will be damaged or their useful life will be shortend (H 6.3.2.1).	Turret heater vents should be equipped with baffles to prevent the discharge of heated air directly onto heat sensitive equipment. This happens when the equipment is moved in front of the ventholes by turret rotation.
Section D. Driver's Station		
1. Workspace (conventional component)		
1.1. Legroom and headroom are inadequate for a large proportion of drivers.	The driver's seat should accomodate 5th through 95th percentile operators in the full range of clothing in either closed or open hatch operation. Adjustment of the seat should allow the driver to operate all necessary controls and optical devices during open or closed hatch modes. Particular attention should be given to open hatch head clearance when the driver's hatch is under or near a rotating turret or weapon (H 7.5.12.2.1).	No change.

Table 1 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
2. Driver's reclining seat (new component)		
2.1. The reclining seat does not provide adequate back support.	Back rest angle should not be more than 110 degrees from horizontal (S 5.12.2.4).	Reclining seats with upper and lower back supports and headrest should provide firm and comfortable support for the driver's upper and lower back and neck in all required modes of operation.
3. Periscope wiper/washer unit (conventional component)		
3.1. Manual wipers are difficult to operate and ineffective.	Windshield wipers and washers should be provided. Provision should be made for manual operation in event of power failure (S 5.12.5.8).	Same as Section C-1.1.
4. Driver's periscopes (conventional component)		
4.1. Periscopes are out of alignment causing disorientation.	Visual displays should povide the operator with a clear indication of equipment or system conditions for operation under any eventuality commensurate with the operational philosophy of the system under design (S 5.2.1).	Driver's periscopes should be arranged such that their fields of view overlap and are closely aligned along the horizontal plane (S 5.12.10.3).*

Table 1 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
5. Steering control adjustment pin (conventional component)		
5.1. The adjustment pin is difficult to lock, release, adjust and is unreliable; sometimes it vibrates loose.	Controls shall be designed so as not to be adversely affected by distortion, shock or vibration of the vehicle (S 5.12.3.1).	No change.
Section E. Tank Exterior		
1. Exterior walking and standing surfaces (conventional component)		
1.1. Exterior walking and standing surfaces become slippery when wet or muddy.	Anti-skid surfaces should be provided where the crew/maintenance personnel must step to perform their tasks (H 7.5.6.4).	No change.
2. Turret overhang (conventional component)		
2.1. The turret must be traversed to gain clearance to the front fuel filler caps.	Items most critical to system operation shall be most accessible. When relative criticality is not a factor, items requireing most frequent access shall be most accessible (S 5.9.4.5).	No change.

Table 1 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
2.2 Access to the sponson stowage boxes is obstructed by turret overhang.	Where accessibility depends upon removal of panels, cases and covers, measures shall be taken to insure that such items are not blocked by structural members or other items (S 5.9.4.1). If covers are hinged, allow space equal to the sweep volume of the cover so the body frame, brackets, etc., will not obstruct its opening (H 5.2.5.3.i).	No change.
3. Armored skirt pins (new component)		
3.1. Skirt pins vibrate loose during travel unlatching skirts and causing significant safety hazards.	The number and diversity of fasteners used shall be minimized commensurate with stress, bonding, pressuriation, shielding, thermal and safety requirements (S 5.9.10.1).	No change.
4. Rear skirts (new component)		
4.1. Mud builds up under the rear skirts and fenders causing an unplanned maintenance problem and causing the tank to stall.	Study operational vehicles resembling the one to be designed. List the maintenance features built into it (H 5.1.2.1.b).	On vehicles with armored skirts, mud removing devices should be used with sprockets, rear fenders, rear skirts and related sponson and hull areas to prevent accumulation of mud around the sprockets which would otherwise require unscheduled maintenance (S 5.12.10.4).*

Table 1 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
Section F. Stowage Facilities		
1. Stowage space (conventional component)		
1.1. Stowage space is inadequate for the following items: 1.1.1. Duffle bags. 1.1.2. Personal equipment. 1.1.3. Food rations. 1.1.4. CVC helmets. 1.1.5. NBC protective mask. 1.1.6. Basic issue items. 1.1.7. Oil and lubricants.	Items to be used by a particular crewmember for his task requirement should be stowed in a convenient and accessible location within the functional area of his station (H 5.2.5). Unused space should be utilized to the maximum extent possible to stow items (H 5.2.5.1).	Adequate and suitable stowage space should be provided for stowing personnel equipment such as sleeping bags, weapons, and duffle bags (S 5.12.10.5).*
2. Stowage accessibility (conventional component)		
2.1. Stowage accessibility is a problem for the following items: 2.1.1. TA-50 clothing and gear. 2.1.2. Personal equipment. 2.1.3. Basic issue items.	The stowage of equipment should follow the functional utilization of each item in the determination of accessibility and location (H 5.2.5).	No change.

Table 1 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
Section G. Maintenance		
1. Heat resistant clothing (conventional component)		
2.1. Heat resistant gloves and blankets were not provided as basic issue items for operator maintenance on the gas turbine tank engine.	Any equipment which, in normal operation, exposes personnel to surface temperatures in excess of 60 degrees C (140 degrees F) as a result of inadvertant contact ... shall be appropriately guarded (S 5.13.4.6).	Any equipment which, in normal operation, exposes personnel to surface temperatures in excess of 60 degrees C (140 degrees F) as a result of inadvertant contact ... shall be appropriately guarded unless heat resistant gloves, blankets or protective clothing is provided for servicing of high temperature items (e.g. turbine engines) is required. (S 5.13.4.6).*
Section H. NBC Warfare		
1. Protective uniform (conventional component)		
1.1. Crewmember effectiveness for performing critical tasks was estimated to decrease by 40 to 45 percent when wearing the protective uniform.	Use of the overpressure collective protection system eliminates the requirement for masks and protective clothing. This eliminates the encumbrance of this equipment and compatibility problems with equipment to be operated (H 3.8.2).	No change.
1.2 Crewmen estimated they can operate effectively for only 2 to 4 hours when wearing the protective uniform.	Same as above (H 3.8.2).	No change.

The HFE problems in Table 1 were distributed across 24 different design features or equipment components. Eighteen of these 24 components were present in previous generation tank designs and thus represent earlier generation technology. The remaining six are unique to the M1 tank and can be viewed as applications of new technology. This division indicates that the design of conventional components is the primary source of major HFE problems. Some of the reasons for this situation are considered below.

Examination of the 18 old design features show that current criteria were available for all of them. The criteria were judged to be adequate for 13 features and inadequate for five. This suggests that 72 percent of the conventional design features which produced major HFE problems could have been avoided if the designers had observed the guidance available in the current criteria. The remaining problems could be assumed to be partly the result of the poorly defined criteria that did not provide the necessary information.

Turning to the six new generation features with major HFE problems, analysis indicates that there were current criteria available for five of them. In three cases, however, the criteria were judged to be inadequate. Thus adequate criteria were available for only two of the new design features; new or revised criteria are required for the other four features. This indicates that only about a third of the major problems with new design features can be expected to be avoided by following available criteria. The other two thirds were not covered by any criteria or had outdated criteria which did not provide the needed guidance. The results suggest that much of the current criteria cannot be applied to new generation design features without first being revised and updated.

Table 2

Comparisons of General HFE Design Problems in the
M1 Tank OT III Report with Current and Proposed Design Criteria

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
Section A. Commander's Station		
1. Crewstation padding (conventional component)		
1.1. The hatch frame is not padded to protect the commander.	Provisions for crew safety should include appropriate padding in areas where crew equipment contact may occur. Each vehicle design and and development program should evaluate its own individual requirements for padding (H 7.5.6.1).	No change.
2. GPS extension (new component)		
2.1. The light level in the gunner's primary sight extension is too low.	Means shall be provided for illumination of reticles, internal and external scales, etc. under low level conditions. Continulusly variable control of illumination shall be provided as required by weapon system characteristics (S 5.11.3.17, H 7.7.7).	No change.

Table 2 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
3. Commanders' weapon sight (conventional component)		
3.1. The commander's weapon sight cannot be efficiently aligned because the screw adjustment control is inaccessible and requires a special screwdriver.	Knobs should be selected in preference to screwdriver adjustments whenever frequent adjustment must be performed (S 5.9.3). Special tools required for operational adjustment should be securely mounted within the equipment in a readily accessible location (S 5.9.1.2).	No change.
4. Machinegun charging cable (new component)		
4.1. The charging cable on the commander's weapon breaks frequently under normal use in the field.	The following provision has been added to Notice 1 to MIL-STD-1472C, 1 Sep 83: "4.9 Ruggedness. Systems and equipment shall be sufficiently rugged to withstand handling in the field during operation, maintenance, supply and transport within the environmental limits specified for those conditions in the applicable hardware or system specification."	No change.
5. Manual traverse ring (conventional component)		
5.1. The arrangement of the manual traverse ring and commander's weapon sight is a safety hazard.	A guard shall be provided on all moving parts of machinery on which personnel may become injured or entangled (S 5.13.7.2).	No change.

Table 2 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
6. Fenders and sponsons (conventional components)		
6.1. Commanders are exposed to flying debris from the tank tracks.	No relevant criteria was found.	Fender and sponson configuration shall prevent debris from striking any exposed vehicle crewmember (S 5.12.10.6).*
7. Master power switch (conventional component)		
7.1. The commander's master power switch can improperly shut down the engine by out-of-sequence operation.	Where sequential operations follow a fixed pattern, controls shall be arranged to facilitate operation (S 5.4.1.3.2). Controls may be combined to aid sequential or simultaneous operation, etc. (H 1.1.1.3.3).	Controls that must be operated in a fixed sequence shall be interlocked to operate only in that sequence if out-of-sequence operation would result in danger to personnel, damage to equipment or failure of a mission (S 5.4.1.3.2).*
8. Stowage space (conventional component)		
8.1. Stowage space is inadequate in the commander's station.	The stowage of equipment should follow the functional utilization of each item in the determination of accessibility and locations. Items used by a particular crew member should be stowed in a convenient accessible location within the functional area of the	No change.

* The proposed change has been reviewed and revised by members of the Tri-Service Technical Group for MIL-STD-1472 and submitted to the group for adoption as a revision of or a change notice to MIL-STD-1472.

Table 2 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
	crew member's station (H 5.2.5). Stowage should be available for doffed personal items such as individual weapons, rations and helmet if donning of other special gear is required when operating equipment (H 5.2.5.2).	
Section B. Loader's Station		
1. Loader's knee guard (conventional component)		
1.1. The knee guard does not provide adequate protection against ejected shell casings.	If spent brass ejection is violent enough to be a hazard to personnel or equipment, appropreate energy absorbers should be provided (H 7.5.11.4). Hot expended cartridge cases/links, should neither come in contact with personnel nor be cast upon their standing surfaces causing them to lose their footing (H 7.5.6.4).	No change.
2. Hatch seals (conventional component)		
2.1. The loader's hatch leaks water during rainy weather.	Mud and water may be impractical to eliminate as problems affecting comfort, but vehicle design should minimize the problem (H 3.11.1).	No change.

(27)

Table 2 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
3. Support handles (conventional component)		
3.1. The loader's station needs another support handle.	No relevant criteria found.	Where support is required for operations in the standing position - either in static or vehicular situations - handgrips should be provided (S 5.7.2.6).*
4. Spent case ejection guard (conventional component)		
4.1. Operating the spent case ejection guard is hazardous.	A safety feature should prevent the gunner or the commander from firing the main weapon while the loader is in the path of recoil (H 7.5.11.3).	No change.
5. Floor ammo racks (conventional component)		
5.1. It is difficult to load main gun rounds from the floor racks.	The design should provide for easy stowage/removal of ammunition by hoist or manual means (H 7.1.1).	No change.
6. Coax MG ammo ready box (conventional component)		
6.1. The coax ammo ready box is grasping ammunition belts laying near the bottom of the box.	Limiting dimensions (reaching test points, handrails, etc.) which restrict or are limited by extensions of the body shall be based upon the 5th percentile values for applicable body dimensions (S 5.6.3.3.).	No change.

Table 2 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
7. Loader's periscope (conventional component)		
7.1. The eye piece on the loader's periscope is difficult to view through and the field of view is poor.	The loader should have an optical device to see ouside of the vehicle during closed hatch operations (H 7.5.11.5). Optical instruments shall be oriented so that they are presented to the operator at an angle comfortable for viewing (S 5.11.3.3). Field-of-view shall be compatible with intended use and optical-mechanical design limitations (S 5.11.3.5).	Displays shall be located and designed so that they may be used to the degree of accuracy required by personnel in the normal operating or servicing positions without requiring the operator to assume an uncomfortable, awkward or unsafe position (S 5.2.1.4.1).*
8. Turret blower (conventional component		
8.1. The turret blower is noisy and drafty.	The noise level within crew compartments should not exceed the limits described in the current issue of MIL-STD-1474 (H 7.5.6.4). Air shall be moved past personnel at a velocity not more than 30 m (100 ft) per minute—20 m (65 ft) per minute if possible. Under chemical-bacteriological or radiological conditions, ventilation requirements should be modified as required (S 5.8.1.2). Proposed Notice 2 to MIL-STD-1472C contains a vehicle vent control provision.	No change.

Table 2 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
9. Loader's intercom box (conventional component)		
9.1. Access to the loader's intercom box is difficult.	Control box location should be chosen so that operators have easy access to controls (H 7.3.8). An item is considered accessible only where it can be operated, manipulated, removed or replaced by the suitably clothed and equipped user with applicable 5th and 95th percentile body dimensions (S 3.1).	No change.
Section C. Gunner's Station		
1. Manual elevation crank (conventional component)		
1.1. The main gun manual elevation crank is located in a poor position.	Controls should be located so that the full range of Army personnel can operate them without having to assume awkward positions (H 7.6.1). The gunner should have both power and manual control of the gun system in elevation and azimuth and should be able to operate them in either mode, without substantial loss of efficiency (H 7.6.1.1).	No change.
1.2. The cord on the manual elevation crank-handle gets entangled when cranking.	The following should be considered in the selection, design, and/or placement of controls: special restraint systems, e.g., electrical leads and connections (H 1.1.1.1.4).	No change.

Table 2 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
2. Two-position lever (conventional component)		
2.1. The thermal magnification lever is located in a position where the gunner cannot see it.	When operators cannot see controls, but must operate them by blind positioning, the most effective coding method is by location (H 1.1.1.4.5.1).	No change.
3. Suspension system (conventional component)		
3.1. Vibration in the gunner's station is intense at slow speeds.	Land vehicles should be designed to control the transmission of whole body vibration to levels that permit safe operation and maintenance as described in MIL-STD-1472C, Figure 42 (See ISO 263) (S 5.8.4.1.1).	No change.
4. Muzzle reference sensor (new component)		
4.1. The muzzle reference reticle is hard to see under nightlight conditions.	Luminous transmission should be as high as possible, preferably greater than 50 percent (S 5.11.3.10.2). Reticle lines shall be thick enough to be easily seen (S 5.11.3.11.1). Illuminated reticles shall be provided for sights to be used during twilight or night operations (S 5.11.3.12.1).	Adjustment range shall permit legibility of reticle lines and markings under all anticipated ambient illuminance conditions (S 5.11.3.12.3).*

(31)

Table 2 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
5. Gunner's intercom box (conventional component)		
5.1. Access to the gunner's intercom box is obstructed.	Same as Section B-9 (H 7.3.8).	No change.
6. Stowage space (conventional component)		
6.1. Stowage space at the gunner's station is inadequate.	Same as Section A-8 (H 5.2.5 and H 5.2.5.2).	No change.
7. Personnel heater (conventional component)		
7.1. Heat distribution in the gunner's station is poor causing discomfort.	Crew heating is required for efficient tank operation. Local space heating at the crew positions will normally be needed (H 3.4.4).	No change.
8. Turret blower (conventional component)		
8.1. The blower is very noisy. It is difficult to understand communications when the turret blower is running.	Same as Section B-8 (H 7.5.6.4).	No change.
9. Gunner's seat (conventional component)		
9.1. It is difficult to enter and leave the gunner's seat.	There should be adequate clearance for the full range of suitably clothed Army personnel to enter/leave the gunner's seat (H 7.5.10.1.3.2).	No change.

Table 2 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
Section D. Driver's Station		
1. Hatch seals (conventional component)		
1.1. The driver's hatch leaks during rainy weather.	Same as Section B-2 (H 3.11.1).	No change.
2. Crew station padding (conventional component)		
2.1. Hatch frame padding protection is inadequate.	Same as Section A-1 (H 7.5.6.1).	No change.
3. Master power switch (conventional component)		
3.1. The driver's master power switch can improperly shut down the engine.	Same as Section A-7 (S 5.4.1.3.2 and H 1.1.1.3.3).	Same as Section A-7.
4. Stowage space (conventional component)		
4.1. Stowage space in the driver's station is inadequate.	Same as Section A-8 (H 5.2.5 and H 5.2.5.2).	No change.
5. Personnel heater (conventional component)		
5.1. The heater overheats and distribution is poor causing discomfort.	Same as Section C-7 (H 3.4.4).	No change.

Table 2 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
6. Turret blower (conventional component)		
6.1. The blower is noisy. It is difficult to understand communications when the turret blower is running.	Same as Section B-8 (H 7.5.6.4).	No change.
7. Driver's intercom box (conventional component)		
7.1. The driver's intercom box is in a poor location.	Same as Section B-9 (H 7.3.8).	No change.
8. Radio (conventional component)		
8.1. Drivers do not have the capability to operate the radio from their crew stations.	Radio control panels should be readily visible and accessible to operators. Operators should be able to reach control panel(s) to change frequency without having to open doors, remove covers, or the like (H 7.3.6).	No change.
9. Fenders and sponsons (conventional component)		
9.1. The front fenders do not protect the driver from flying debris when operating in the open hatch mode.	No relevant criteria found.	Same as Section A-6.

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Table 2 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
Section E. Tank exterior		
1. Tow eyes (conventional component)		
1.1. Both sets of the front tow eyes are difficult to work with under field conditions.	Connectors should be compatible with the environmental extremes to which they will be subjected and the maintenance routines they are involved in (H 5.9.1.1).	No change.
2. Grille doors (conventional component)		
2.1. The rear grille doors are fragile and are easily damaged.	The Army program for material readiness emphasizes reliability in design (H 5.1.1).	No change.
3. Roadwheel hub plugs (new component)		
3.1. The roadwheel hub plugs leak when washed down with water hoses.	Designing for maintainability should include testing the design (H 5.1.2).	No change.
4. Main gun muzzle cover (conventional component)		
4.1. The muzzle cover for the main gun does not fit properly.	Same as above (H 5.1.2).	No change.
5. Wind sensor (new component)		
5.1. The wind sensor is exposed to damage hazards.	Are easily damaged components mounted or guarded so they will be protected (H 5.21.i)?	No change.

Table 2 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
6. Engine Transmission (conventional component)		
6.1. The transmission needs a drain system to drain off excess oil from overfilling.	No relevant criteria found.	Overflow drains shall be provided where overfilling of lubricant levels must be avoided (S 5.9.5.1).*
Section F. Stowage Space and Maintenance		
1. Spare track sections (conventional component)		
1.1. There is no provision to carry spare track sections on the tank.	Maintainability depends on accessibility of parts (H 5.5.1).	No change.
2. Firing cable (conventional component)		
2.1. The bracket holding the firing circuit cable obstructs maintenance of the main gun.	The disassembly or removal of parts that are in the way of easy access to a part needing maintenance is highly undesirable, especially under field conditions (H 5.5.1). Items most critical to system operation and which require rapid maintenance shall be most accessible (S 5.9.4.5).	No change.

Table 2 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
3. Engine oil dipstick (conventional component)		
3.1. The quart scale on the engine oil dipstick has minus (-) symbols missing causing confusion.	When positive and negative values are displayed around a zero point, the positive values shall increase up from the zero point and negative values shall increase down from the zero point (S 5.2.3.2.4.2).	No change.
4. PMCS (conventional procedures)		
4.1. Many before-operation PMCS tasks are assigned as after-operation PMCS tasks.	Test development and production models for maintainability with representative Army personnel under operational conditions (H 5.1.2.3).	No change.
5. Basic issue items (conventional components)		
5.1. The following tools and devices are not listed in the TO&E for performing PMCS and organizational maintenance.	Tools which will be needed may be identified early in the planning stages from evaluations of necessary maintenance operations and the proposed design of prime equipment (H 5.4.1.1).	No change.
a. An oil spout for oiling roadwheels.		
b. A high-pressure grease gun.		

Table 2 (continued)

M1 TANK OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
c. Two ratchets for tightening track connectors. d. A tool set for performing field maintenance on the suspension system. e. A special screwdriver for operating/maintaining the radios on command tanks. f. Tool bags made of more durable material. g. One 1-1/2 inch socket. h. One wedge-bolt tool.		

The HFE problems in Table 2 were distributed across 46 different design features. Forty-one of these problems were related to conventional technology and five related to new generation components. This division indicates that failure to recognize or consider problems with previous tank systems is the predominant source of general HFE problems in new tank designs; difficulties associated with new design features account for only about 11 percent of the general problems.

Examination of the 41 conventional design features with problems shows that current criteria were available for 37 of them; no specific criteria were found for the other four. The criteria were judged to be adequate for 34 features and inadequate for three. Thus, approximately 83 percent of the M1 tank's conventional design features which had general HFE problems could have been circumvented if the designers had followed the guidance available in the current criteria. The remaining 17 percent are assumed to result partly from missing or inadequate criteria. This latter result indicates that a substantial portion of conventinal system design features which caused HFE problems were not covered by adequate criteria. These results are in agreement with the findings for major HFE problems.

Turning to the five new generation features (components) with HFE problems, analysis indicates that there were current criteria available for all of them; four had criteria judged to be adequate and one had inadequate criteria. This result shows that a much greater proportion of current criteria was judged to be adequate for new components causing general HFE problems (80 percent) than for new components causing major HFE problems (33 percent). The discrepancy may be due primarily to the small sample sizes involved in the comparison. When the two samples are combined, the comparisons show that 54 percent of the new components with either major or general HFE problems were covered by adequate criteria and the remaining 46 percent with inadequate criteria. This overall assessment suggests that a large proportion of the criteria for guiding the design application of new technology to tank systems needs to be revised and updated.

SUMMARY AND CONCLUSIONS

This report has identified current (previously existing) criteria and developed new and revised criteria critical for the HFE design of future tank systems. Four general findings emerged from the analysis of HFE problems identified in the test report: Independent Evaluation of the M1 Main Battle Tank (November 1981).

1. Poor designs associated with conventional generation technology and present in previous tank systems accounted for about 84 percent of the M1 tank's HFE problems. New technology and equipment designs unique to the M1 tank system accounted for the remaining 16 percent of the M1's problems.

2. Of the HFE problems common to both the M1 tank and previous similar systems, approximately 80 percent are covered by current criteria which provide adequate guidance for resolving such problems. These problems make up about two-thirds of the HFE problems in the M1 tank system and could have been avoided had greater attention been paid to the design rules already available in current criteria.

3. Twenty percent of the problems common to both the M1 tank and previous similar systems were related to inadequate design criteria that did not provide the required information. This finding indicates that the current (previously existing) criteria are of uneven quality. A substantial proportion needs to be revised in order to provide the specific, unequivocal information that is needed for guiding the design process.

4. The situation with new technology is much different. Only about 54 percent of the HFE problems designed into components new to the M1 tank were found to be covered by adequate criteria; 36 percent had inadequate criteria; nine percent had no criteria. These findings indicate that a large proportion of the current criteria in MIL-STD-1472C (1981) and MIL-HDBK-759A (1981) do not contain the information sufficient for incorporating good HFE design into new technology. The new technology contains novel design features that are not addressed by current criteria. This situation indicates a severe limitation in the capacity of previous criteria to provide adequate design guidance for new technology. It points out a definite need to update old design criteria and add new criteria concurrently with applications of new technology. The new and updated criteria should be available when new technology is being designed into new tank systems.

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